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The Nature of 3EG J1746-2851 in the Nucleus of the Galaxy

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Abstract. There are a number of candidate sources that are considered to be responsible for the origin of the EGRET source 3EG J1746-2851 (Hartman et al. 1999). The lack of clear identification of this source with any known sources in this region is due to the complexity and the richness of the environment of the Galactic center as well as the low spatial resolution of the EGRET observations. Four hypotheses, which include the interaction of something with something else, are described to account for the energetics and the spectrum of the γ -ray emission from the enigmatic EGRET source which lies within 0.2° of the Galactic center. The possible interaction sites result from the following: i) the nonthermal filaments of the radio Arc & G0.13-0.13 molecular cloud, ii) the supernova remnant Sgr A East & the 50 km s^{-1} molecular cloud, iii) the magnetized filaments of the Arc & M0.20-0.033 molecular cloud and iv) the relativistic particles of the Arches cluster & its own stellar radiations field.

1. Introduction

In a recent paper, Yusef-Zadeh, Law and Wardle (2002) argued that the molecular cloud G0.13-0.13 is interacting with the nonthermal radio filaments of the Arc (Yusef-Zadeh, Morris & Chance 1984) and is responsible for the enhanced 6.4 keV line emission at the interface between these two features. This argument was also used in support of an earlier interpretation by Tsuboi et al. (1997) and Oka et al. (1997) who showed the morphological and dynamical evidence for such an interaction. Figure 1 shows radio continuum image of the straight non-thermal filaments (red color), the G0.13-0.13 cloud (contours) and the diffuse and filamentary X-ray features (green color) lie within the 95% error circle of an unidentified EGRET source 3EG J1746-2851 (blue color) (Hartman et al. 1999), with a steady source of strong γ -ray emission between 30 MeV and 10 GeV. The photon index is $\alpha=1.7\pm0.7$, and its flux is estimated to be 1.2×10^{-6} photons $\text{cm}^{-2} \text{ s}^{-1}$ with energies greater than 100 MeV, corresponding to 10^{40} photons s^{-1} at the distance of the Galactic center (Hartman et al. 1999).

3EG J1746-2851 is interpreted in terms of the interaction of the nonthermal filaments with the molecular cloud. The $E^{-1.7}$ photon spectrum of 3EG J1746-2851 matches onto the cloud spectrum at about 10 keV when extended down to X-ray energies. This suggests that the EGRET source is produced by bremsstrahlung, and that the electron spectrum extends up to GeV energies with

an $E^{-1.7}$ dependence in this range. This model is supported by the spectral index measurements of the nonthermal filaments between cm and mm wavelengths. The spectral indices (p , where $S_\nu \propto \nu^p$) are positive along the vertical filaments of the Arc but there is an anomalous filament near G0.16-0.15 with $p \sim -0.35$ (Anantharamaiah et al. 1992), consistent with synchrotron emission from GeV electrons with an $E^{-1.7}$ spectrum.

Another interpretation of the EGRET source considers that the relativistic particles of the nonthermal supernova remnant Sgr A East near the Galactic center is interacting with the 50 km s^{-1} molecular cloud (Melia et al. 1998). The bright oval-shaped structure to the southwest of Figure 1 shows Sgr A East. The black spot drawn on Sgr A East coincides with Sgr A*, the massive black hole at the Galactic center. The p-p scattering resulting from this interaction generates pions which eventually decay into γ -rays. These authors show that the electron-positrons produced from pion decays fit the radio spectrum of Sgr A East well. Both Sgr A East and Sgr A* exclude the 95% error circle of the EGRET source. However, the EGRET source could include Sgr A East if the γ -ray emission is extended.

Another scenario involves the possibility that the EGRET source results from the motion of a molecular cloud M0.2-0.033 pushing against the flux tubes of the nonthermal radio filaments of the Arc (Pohl 1997). The HII region G0.18-0.04 is at the interaction zone between these two features. The relativistic particles of the nonthermal filaments with a monoenergetic electron distribution are then responsible for Compton scattering of far-IR photons of the molecular cloud G0.2-0.033.

Lastly, the source of γ -ray emission could arise from the Arches cluster (e.g. Blum et al. 2001) which lies within the 95% error circle of 3EG J1746-2851. The remarkable cluster is embedded within an HII complex and its location is drawn as a cross in Figure 1. This cluster consists of mainly 150 O star candidates with stellar masses greater than $20 M_\odot$. The Arches cluster is $\sim 15''$ across, with an estimated density of $3 \times 10^5 M_\odot \text{pc}^{-3}$ within the inner $9''$ (0.36 pc) of the cluster (e.g. Cotera et al. 1996; Serabyn, Shupe & Figer 1998; Blum et al. 2001). The ensemble of colliding winds within the cluster will produce shock waves that can accelerate particles to high energies. The relativistic particles of the cluster can then be used to produce γ -ray emission by scattering of the IR radiation field of the cluster. A more detailed account of this proposal will be given elsewhere.

In conclusions, we believe an understanding of the origin of the EGRET source toward the Galactic center yields insights into the physical processes occurring in the interaction sites described here. There may be interesting aspects of this interaction picture that can be applied to the nuclei of normal galaxies or AGNs even if the γ -ray emission is not produced by the massive black hole at the dynamical center of the Galaxy. Future γ -ray observations of this region with Integral should be useful to clarify the nature of the enigmatic source 3EG J1746-2851.

Figure 1. A $\lambda 20$ cm continuum image of the nonthermal Sgr A East to the southwest and the filamentary Arc to the northeast is shown in red. The black spot drawn near the center of the Sgr A East shell coincides with the position of Sgr A*, the massive black hole at the Galactic center. The cross indicates the position of the Arches cluster which is surrounded by curved ionized features known as the arched filaments. The distribution of 3EGJ1746-2851 is shown in blue. The radius of the 95% error circle is $0.11''$ (Hartman et al. 1999). The distribution of X-ray emission near the filaments of the Arc is shown in green whereas the distribution of CS (1–0) molecular line emission is represented as yellow contours. Note that the distribution of molecular gas and X-ray emission from the regions of Sgr A East and the arches cluster are not shown in this figure. (The color version of this figure is available in astroph)

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